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Interference characteristics of dual-standard monochrome television receivers operating in the u.h.f. bands

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INTERFERENCE CHARACTERISTICS OF DUAL-STANDARD MONOCHROME TELEVISION RECEIVERS OPERATING IN THE U.H.F. BANDS

Head of Research Department

C.R.G. Reed, M.A.(Oxon.), C.Eng., M.I.E.E.

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Summary

This report gives the results of a series of measurements made in 1970 on the interference-rejection characteristics of six British monochrome dual-standard (Systems A and I) receivers operated in the u.h.f. bands (Bands IV and V) using System I.

1. Introduction

The design of television receivers is developing continuously and in order to assist in realistic planning of the network of u.h.f. transmitters information on some of the operating characteristics of recent dual-standard monochrome receivers is required. The models tested, all of which were of British manufacture and available in 1969, are referred to in the text as Receivers A to F.

The methods of measurement and the results are generally in accordance with the appropriate British Standard[1,2] but some departures from these standards are noted.

The measurements are related to susceptibility to interference by other signals, to a.g.c. performance or to the level of the voltage at the receiver oscillator frequency appearing at the aerial terminal. All measurements were made in the u.h.f. bands (Bands IV and V) using 625-line signals (CCIR System I as used in the U.K.).

A large proportion of the measurements consisted of subjective assessment of the interference. In these, the level was found at which interference was 'just perceptible' (Grade 2 on the CCIR six-point impairment scale[3]). It would have been uneconomic to use a panel of viewers to assess every condition so all the tests were carried out by one engineer who checked that his assessments of 'just perceptible' levels of interference in a few particular tests agreed closely with those of a small group of engineers who were practised in making assessments of picture quality. The procedure was justified because the tests made on these receivers involved only decisions as to whether or not an interference was perceptible and did not involve any judgements of the relative merit of pictures subject to different forms of degradation.

Some items of test equipment were used in more than one test. To avoid repetition these are described in an Appendix. The results are usually stated in terms of the open-circuit e.m.f. in a 75 Ω source which is to be applied to the aerial socket of the receiver on test. The relation-ship between this e.m.f. and the corresponding field strength at a receiving aerial depends on the channel being used, the gain of the aerial in the direction of the transmitter and the loss in the feeder. For example, a field strength of N dB (μV/m) on Channel 45 (λ = 0·447 m) would induce into a half-wave dipole an e.m.f. of $(N + 20 \log \lambda/\pi) = (N - 17·5)$ dB (μV). If the aerial gain were 10 dB and the feeder loss 3 dB the e.m.f. at the end of the aerial lead would be $(N - 17·5 + 10 - 3) = (N - 10·5)$ dB (μV).

The following notation is used in this Report for the frequencies of carriers and oscillators encountered in the various modes of interference:

V(n) ≡ Vision carrier frequency of Channel n, (MHz)

S(n) ≡ Sound carrier frequency of Channel n, (MHz)

O(n) ≡ Receiver oscillator frequency when correctly to Channel n, (MHz)

The standard vision intermediate frequency (i.f.) in the U.K., as agreed by members of the British Radio Equipment Manufacturers Association, is 39·5 MHz, and the sound i.f. is 33·5 MHz: if a receiver is tuned ideally to Channel n, O(n) = V(n) + 39·5

$$= S(n) + 33·5$$

2. Amplitude response of the receiver near and within the frequency channel of the wanted signal

2.1. Scope of the tests

This Section deals with measurements of the overall response of the vision channel of the receiver and the effectiveness of the rejection of interference from the sound carrier of the wanted signal or from signals on adjacent channels. The measurements usually require some modifications to the receiver to over-ride the action of the a.g.c. system but these are usually fairly simple and explained in detail in the manufacturer's instructions for aligning the i.f. stages.

The available methods of measurement are well known and are summarised in the following Section. The results of applying some of these methods will be given in Section 2.3.

2.2. Methods of measurement used in the tests

Four methods were used for measuring the frequency response, in each of which the a.g.c. action was replaced by a fixed bias in accordance with the manufacturer's instructions. In a fifth, confirmatory test the levels of c.w. signals 2 MHz above and below carrier frequency were compared when each in turn was adjusted to give just-perceptible interference when receiving a transmission modulated with Test Card F, the a.g.c. circuits operating normally.

(i) A c.w. signal was injected into the first i.f. tuned circuit (contained in the u.h.f. or v.h.f. tuner unit), a series 10 kΩ resistor preventing undue loading of the tuned circuit by the signal generator. Access to the test point is difficult in some receivers.

The d.c. level at the detector was monitored, using a d.c.—coupled oscilloscope with a high-im-pedance probe, and the generator frequency was varied over the range that includes the i.f. passband and the notches which reject the sound channel and the carriers of the adjacent-channels (e.g. 31 to 42 MHz). The generator output level was adjusted to maintain a constant d.c. output from the detector.

(ii) This method was similar to the above except that the 10 kΩ resistor was replaced by a 100 pF capacitor.

(iii) Two u.h.f. signals were added and fed into the receiver's aerial socket (Fig. 1), the a.c. output from the detector[4,5] being measured by an oscilloscope with a high-impedance probe. The generator outputs were adjusted in a series of operations:

a) The output from the 'variable frequency generator' was switched off and the 'carrier frequency generator' was 100% square-wave amplitude modulated at 1 kHz. The carrier frequency was set for maximum response at the detector output and the carrier level set for a conveniently large detector output without perceptible overloading of the receiver

b) The carrier frequency was then reduced until the detector voltage output was halved, this being a first approximation to the correct carrier fre-quency.* The modulation was switched off and the c.w. level set to one-half of the peak level of the modulated waveform.

c) The variable-frequency c.w. generator was switched on and its level adjusted to 10 dB below that of the carrier-frequency generator. It was tuned so that the corresponding signal in the i.f. stages was at the frequency of the sound-rejection notch in the receiver response, indicated by a minimum of the output from the detector.

d) The frequency of the carrier generator was adjusted so that the beat between the two carriers, measured by the digital frequency meter, was at 6 MHz.

The variable-frequency generator was then tuned through the passband and rejection notches and the a.c. output from the detector plotted against the reading on the digital frequency meter.

(iv) This method only differed from (iii) above in that the oscilloscope was connected between the display-tube cathode and earth so that the response of the video stages was included, whereas the previous method indicated the effects of the stages up to the detector.

(v) This test consisted of a subjective assessment of the rejection of a c.w. signal at the frequency of the lower-adjacent sound-channel. A signal on Channel 33, received from Crystal Palace, was filtered to remove other transmissions and amplified. This was com-bined with the c.w. output from a calibrated u.h.f. oscillator in a directional coupler (see Section 13.4 of the Appendix) and both signals were applied simultaneously to a standard u.h.f. test receiver (see Section 13.2 of the Appendix) and, through a 50Ω to 75Ω resistive matching pad (Section 13.3 of the Appendix), to the broadcast receiver on test.

The level of the Channel 33 signal into the receiver under test was set in turn to a few values between 70 and 80 dB(μV). At each of these levels

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* Receivers for the v.s.b. television system normally attenuate the carrier frequency by about 6 dB relative to the frequency of maximum response.
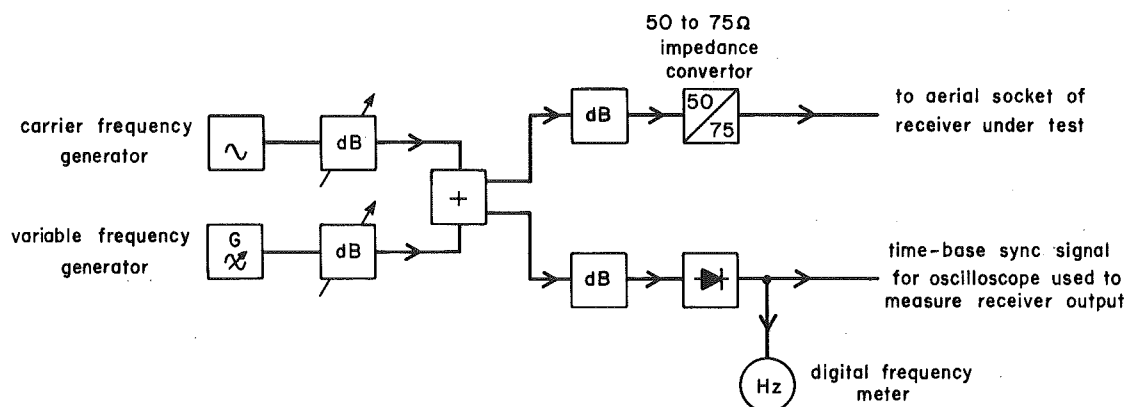

Fig. 1 - Two-signal method of measuring frequency response

of the wanted signal the oscillator signal frequency was adjusted, using a digital frequency counter, to $V(33)-2 = 565\cdot25$ and $V(33)+2 = 569\cdot25$ MHz and the oscillator levels found at which each 2 MHz pattern was just perceptible. In each test the frequency was varied by approximately ±1 kHz to avoid the conditions at which the visibility of interference was especially low.

2.3. Results

The response curves of one receiver (Receiver A), obtained by the four methods, are shown in Fig. 2. The differences between them underline the need to know the method of measurement when interpreting a frequency response curve.

Of these methods of measurement, the last is the one which most closely represents normal operating conditions. Defining the wanted vision carrier frequency as being 6 MHz below the wanted-channel sound rejection notch, the results for four receivers using this method are summarised in Table 1.

TABLE 1

Selectivity characteristics of four receivers

Receiver	A	B	C	D	
Ratio of peak response to response at wanted vision carrier	+5	+5	+3	+8	dB
Response at wanted channel sound rejection notch:					
relative to vision carrier	−37	−42	−41	−20	dB
relative to peak	−42	−47	−44	−28	dB
Response at lower-adjacent-channel sound*					
relative to wanted vision carrier	−26	−26	−34	−25	dB
relative to peak	−31	−31	−37	−33	dB
Bandwidth over which response is greater than that at vision carrier	4·3	4·4	4·3	5·5	MHz

* In some receivers there is a notch in the frequency response at this frequency while others rely on the steepness of the skirt of the response curve.

In the subjective tests the mean values of the ratios of the levels of the interfering signals at frequencies $V(33)+2$ MHz and $V(33)-2$ MHz, for three of the receivers, were

Receiver A	44 dB
Receiver B	44 dB
Receiver C	52 dB

These are 13 to 15 dB greater than the corresponding figures measured by the objective two-signal methods, probably because the minima in those methods are seriously masked by noise. One of the difficulties which is involved in both methods, but more particularly the subjective methods because of the very low amplitude of interfering signal required at $V(33)+2$ MHz, is that there must be an extremely low level of leakage past the attenuator that controls the c.w. signals, otherwise its setting will not indicate the signal level.
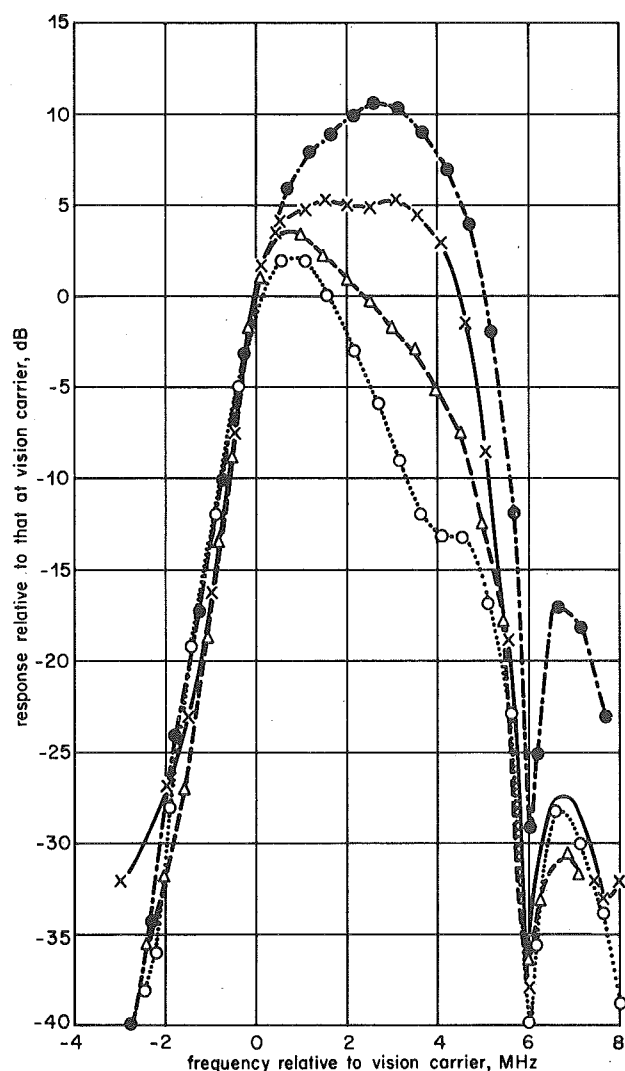
Fig. 2 - Frequency response, Receiver A

O······ c.w. input at i.f. through 10 kΩ, d.c. level at detector constant

●—·— c.w. input at i.f. through 100 pf, d.c. level at detector constant

△—— two c.w. inputs at r.f., output measured at detector load

X—— two c.w. inputs at r.f., output measured at the display-tube cathode

3. Interference by signals on an adjacent channel

3.1. The mechanism of the interference

If a receiver is correctly tuned to a signal with modulated vision and sound channels at u.h.f. carrier frequencies $V(n)$ and $S(n)$ the corresponding i.f. carriers are 39·5 and 33·5 MHz respectively.

The sound carrier frequency of the lower adjacent channel, $S(n-1)$, is 2 MHz below the wanted vision carrier $V(n)$ so the corresponding i.f. signal is at 41·5 MHz. It was shown in the previous Section that the responses of three receivers at $S(n-1)$ varied from approximately 44 to 52 dB below peak response. Interference from the lower adjacent channel tends to be seen as vertical bars corresponding to a video frequency of 2 MHz with some disturbance from the frequency modulation of the interfering sound channel.

The bar pattern is independent of the receiver tuning but the contrast depends critically on the accuracy with which the receiver is tuned because this controls the attenuation of the interfering signal, particularly when there is a corresponding rejection notch in the i.f. response.

The vision carrier of the upper adjacent channel, $V(n+1)$, is 8 MHz above the wanted vision carrier $V(n)$ with the corresponding i.f. component at 31·5 MHz. Rejection of this frequency in the i.f. stages generally depends on the steepness of the skirt of the i.f. response curve rather than on a specific rejection notch. If the interference is strong enough to be visible it appears as a distorted version of the interfering signal, principally of its line synchronising pulses unless these reach the receiver during the line blanking periods of the wanted signal, or as high-frequency noise, the visibility of the interference depending to some extent on the tuning of the receiver. Under adverse conditions the interference may also be apparent as an increase in the noise level of the sound channel.

3.2. Equipment used for the measurements

The two signals involved in the test were controlled in the manner shown in Fig. 3.

One of the signals was the BBC-2 transmission from Crystal Palace on Channel 33 (vision carrier 567·25 MHz). Other broadcast channels were removed by a 565 to 575 MHz bandpass filter before the signal was amplified, to avoid cross-modulation effects in the amplifier. The other signal was generated on Channel 32 by the modulator and frequency convertor described in Section 13.5 of the Appendix. The sound channel was sine-wave frequency modulated (50 kHz peak deviation) at 1 kHz and the vision signal was modulated by a Test Card. The unwanted outputs from the convertor were removed by a 556 to 566 MHz bandpass filter before the signal was amplified.

The two signals were combined in a directional coupler (Section 13.4 of the Appendix) whose output could be arranged to feed the broadcast receiver on test or a u.h.f. test receiver (Section 13.2 of the Appendix). Alternatively the test receiver could be calibrated by reference to a u.h.f. signal generator.

3.3. Method of measurement

The frequency of the vision carrier of the Channel 32 signal was adjusted using the u.h.f. digital frequency meter, with both the 6 MHz sound subcarrier and the video modulation removed (See Section 13.5 of the Appendix). The Channel 32 sound subcarrier and vision modulation were then switched on and the u.h.f. test receiver was tuned to each sound and vision carrier in turn. The gain of the receiver was known to vary very little over this frequency range and its attenuators were used to check that each signal had the appropriate 7 dB ratio between the vision carrier peak amplitude and the sound carrier amplitude.

The output from the directional coupler was transferred to the broadcast receiver on test, which was tuned to the wanted channel. When this was Channel 33, measurements were made only when the radiated programme was Test Card F or a caption chart, partly because these gave high-definition pictures by which the accuracy of the receiver tuning could be judged and partly because they were relatively free from source noise which would mask the interference.

The tests were made on Receivers A, B and C. At several levels of the wanted signal the interfering signal was switched off and the receiver adjusted for optimum picture (including the setting of the brightness, contrast and tuning controls). The level of the interfering signal was then raised until it caused just-perceptible interference (Grade 2 on the CCIR six-point impairment scale[3]).
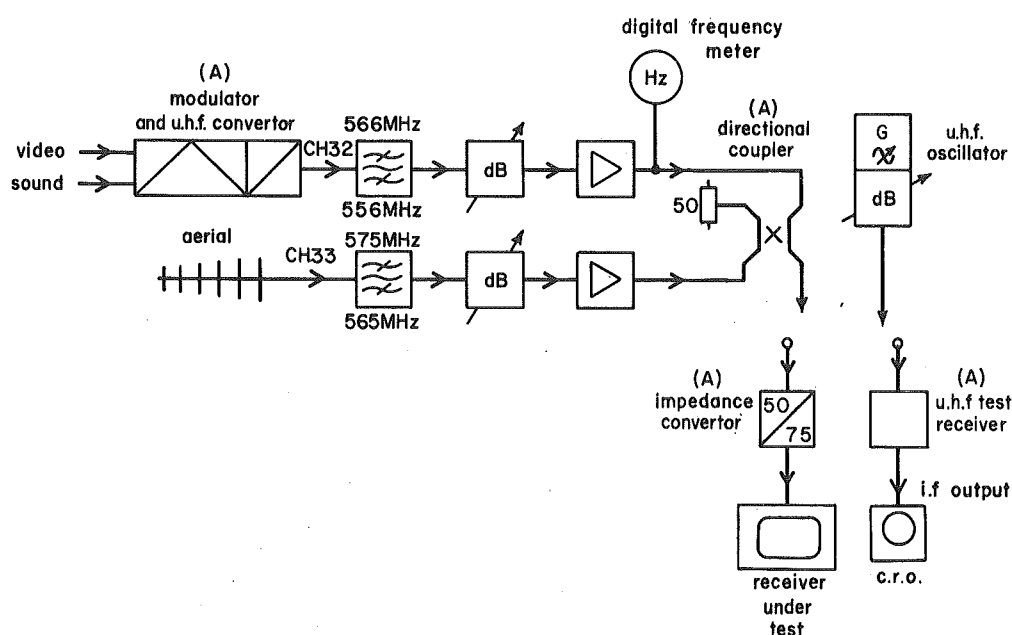

Fig. 3 - Equipment used for measuring the susceptibility of a receiver to adjacent-channel interference

(A) Units described in the Appendix to the report

3.4. Results

3.4.1. Interference by a signal on Channel 32 with a wanted signal on Channel 33

The results of the tests on the three receivers are shown in Fig. 4. The mean of the results is given by curve (1) which corresponds to a required protection ratio for just-perceptible interference of approximately 3 dB except for input levels below 60 dB/μV when the receiver noise tends to mask the interference.
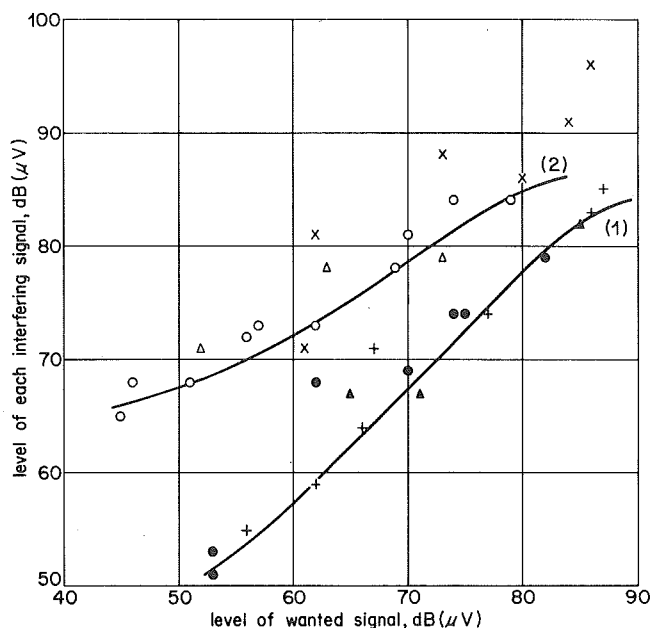

Fig. 4 - The susceptibility of a receiver to interference on the adjacent-channel

		Receiver
		A B C
(1)	Interference by Channel (n—1)	+ ● ▲
(2)	Interference by Channel (n+1)	X O △

CCIR Recommendation 418-2,[6] Section 3.2, gives the required protection ratio as —6 dB for interference present for a small percentage of the time (usually this is taken as being Grade 3 to Grade 4 on the six-point impairment scale) with the note that protection ratios for just-perceptible interference (Grade 2) 'would be some 10 to 20 dB higher'. A correction factor often used is 12 dB; on this basis the receivers reject the lower adjacent channel slightly more effectively (by 3 dB) than is assumed in the CCIR Recommendation.

3.4.2. Interference by a signal on Channel 33 with a wanted signal on Channel 32

The results of the tests on the three receivers are shown in Fig. 4. The mean of the results is given by curve (2) which corresponds to a required protection ratio for just-perceptible interference of —8 dB at signal levels between 70 and 90 dB(μV), with some masking of the interference at lower levels by the receiver noise.

CCIR Recommendation 418-2 gives the protection ratio for interference present for a small percentage of the time (see Section 3.4.1) as —12 dB. If corrected for continuous interference this would indicate 0 dB protection ratio, a somewhat higher value than that indicated in the tests. The difference lies in the attenuation of the lower sideband of the channel (n+1) transmission. It is likely that the CCIR figure is appropriate where the v.s.b. filter characteristic just meets the UK specification[7] allowing linear cross-talk to become just perceptible. However, the v.s.b. filter used in the present tests had a much greater out-of-band attenuation. As a result, interference was not seen until it reached a level at which non-linear cross-modulation occurred; this level corresponds to a lower protection ratio. Thus the results in Fig. 4 and the CCIR figure may be regarded as lower and upper bounds, respectively, depending on the overall response of the transmitter or relay station which is the source of interference. For planning purposes, however, the CCIR value must be adopted since the transmitter cannot normally be relied upon to provide better filtering than is specified.

4. Interference by a transmission separated from the wanted signal by two or three channels

4.1. Mechanism of the interference

If a u.h.f. receiver is tuned to Channel n a single interference on Channel (n±2) or Channel (n±3) normally combines with the receiver's local oscillator to produce components well outside the passband of the i.f. amplitude stages, but if the interference is strong enough it may become visible as a result of cross-modulation in an odd-order nonlinearity of the r.f. stages of the receiver. These tests were not extended to Channels (n±4) because this relationship between channels available in any one area could lead to more serious interference with reception of the higher channel by radiation from the oscillators of receivers tuned to the lower channel[8] (see Section 9) than would result from intermodulation between the signals.

4.2. Method of measurement

The equipment and method of measurement were basically the same as those described in Section 3 and Fig. 3, except that the frequency convertor and its bandpass filter were tuned to Channel 35 or Channel 36, and once again measurements with Channel 33 used as the wanted signal were only made when the modulation was Test Card F or a high-grade caption.

4.3. Results

Fig. 5 shows the results of approximately 40 measurements on four receivers (A, C, E and F). The points marked as lozenges and curve (1) relate to interference by a Channel 35 interference with a wanted signal on Channel 33, using Receiver F, and are typical of the results. The other points represent measurements on other receivers at this channel spacing and also measurements of interference by Channel (n—3) and Channel (n+3).
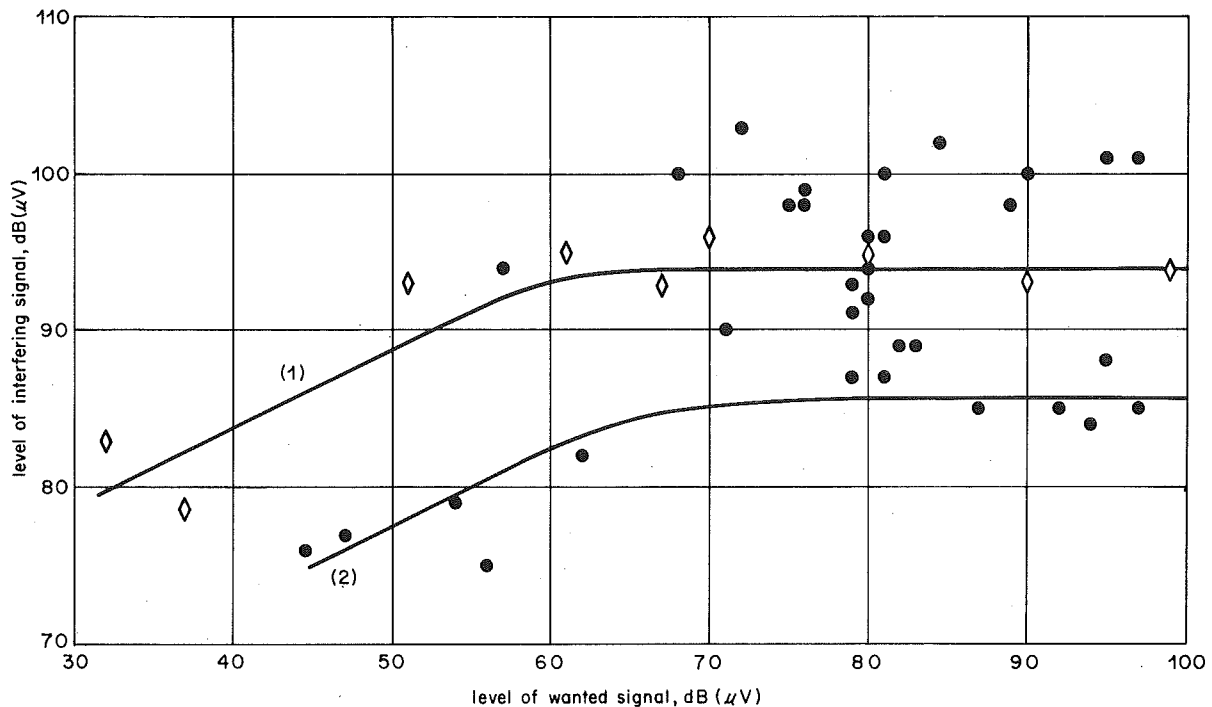
Fig. 5 - Interference by a transmission separated from the wanted transmission by two or three channels

◊   Just-perceptible interference by a transmission on Channel (n+2) using Receiver F

●   Just-perceptible interference involving a different interfering channel and/or receiver

Curve (1) Mean of points ◊   Curve (2) Level below which interference is unlikely to be perceptible on any of the receivers tested

The scatter between the results hides any consistent differences between receivers or between the various channel spacings between the wanted and interfering signals. This scatter is believed to be associated mainly with variations in setting of the brightness and contrast controls of the receivers and in variations of the ambient illumination. The visibility of the interference also depends on whether the line synchronising pulses of the interfering signal occur during the active line time of the wanted signal, but in these tests the timings of the two signals were controlled independently and the interfering signal pattern drifted slowly across the screen so that the dominant interference component in each test was due to the line sync pulses.

Curve (2) of Fig. 5 may be taken as giving the level below which interference of this type is unlikely to be visible, being approximately 85 dB(μV) for wanted signal levels above 75 dB(μV), and falling to approximately 75 dB(μV) for a wanted signal level of 45 dB(μV) when the interference tends to be masked by noise.

5. Interference by a signal on Channel (n+2) in the presence of a third signal on either Channel (n+4) or Channel (n—2)

5.1. The mechanism of the interference

When three signals at frequencies f_1, f_2 and f_3, such that f_2 is the arithmetic mean of f_1 and f_3, are applied to a receiver the non-linearity of the r.f. stages results in interference components in the frequency changer at each of the

input frequencies. Each signal frequency may be regarded in turn as that of the wanted signal, and with the other two frequencies representing interference signals.

If it is assumed that

(i)   the applied signals are c.w.

(ii)   the r.f. response can be characterised by a single, third-order non-linearity

(iii)   the two interfering signals are equal to one another in amplitude, but may vary relative to the amplitude of the wanted signal

(iv)   the a.g.c. maintains the level of the wanted signal constant at the detector,

then graphs drawn on linear scales of dB(μV) of the level of the interfering signals plotted against the level of the wanted signal, for a constant output ratio of interference to wanted signal, can be shown to be straight lines such that

(a)   if the receiver is tuned to f_1 or f_3 the gradient of the line is unity if the a.g.c. is applied wholly before the non-linearity but is 1/3 if the a.g.c. is applied wholly after the non-linearity

(b)   if the receiver is tuned to f_2 the gradient of the graph is again unity if the a.g.c. is applied wholly before the non-linearity but is zero if the a.g.c. is applied wholly after the non-linearity.

The conditions in a receiver are more complicated than this because:

(i) there are usually two or three transistors, including the frequency changer, whose non-linearities are involved and which are coupled by frequency-selective networks

(ii) the laws of the non-linearities vary with the a.g.c. bias

(iii) the a.g.c. operates before, at and after the non-linearities and the a.g.c. delay may not be the same for all stages. Also, no a.g.c. system maintains an absolutely constant level of receiver output

(iv) the receiver signals are not sinusoidal but are either amplitude-modulated with v.s.b. characteristics or, in the case of the sound carriers, are frequency modulated. When the interference occurs between three equally-spaced television channels it involves six carriers — sound and vision for each channel — but in practice only the effects of the vision carriers are significant.

For these reasons the graphs may not be straight and their gradients will lie somewhere between the limits described.

5.2. The method of measurement

The wanted signal was the BBC-2 transmission on Channel 33, filtered and amplified. One of the interfering signals, on Channel 35, was generated by the modulator and frequency convertor described in Section 13.5 of the Appendix and used in the tests described in Section 3 and 4, while the third signal, on either Channel 31 or Channel 37 was the c.w. output from a u.h.f. oscillator. These signals were combined using directional couplers (Section 13.4 of the Appendix).

The peak levels of the interfering signals were made equal to one another with the aid of the u.h.f. test receiver and a calibrating oscillator. The combination of the three signals was then fed into the receiver under test which was tuned carefully to Channel 33. The level of the wanted signal was adjusted so that the intermodulation interference was just perceptible, the frequency of the c.w. signal being varied slightly to ensure that the frequency relationship between the signals included that giving maximum visibility of the interference pattern. Confirmation that the interference was an intermodulation effect was obtained by ensuring that it disappeared if *either* of the interfering signals was attenuated. The levels of the three signals were measured, using the u.h.f. test receiver, and the test was repeated at a series of levels of the (equal) interfering signals.

5.3. Results

5.3.1. Interference by signals on Channels (n+2) and (n+4)

Receivers A and E were tested, and it was found that the intermodulation interference was not perceptible until the levels of the interfering signals were higher than were required for either to be visible as a single interference, i.e. greater than approximately 95 dB(μV) for these receivers at wanted signal levels above 70 dB(μV).
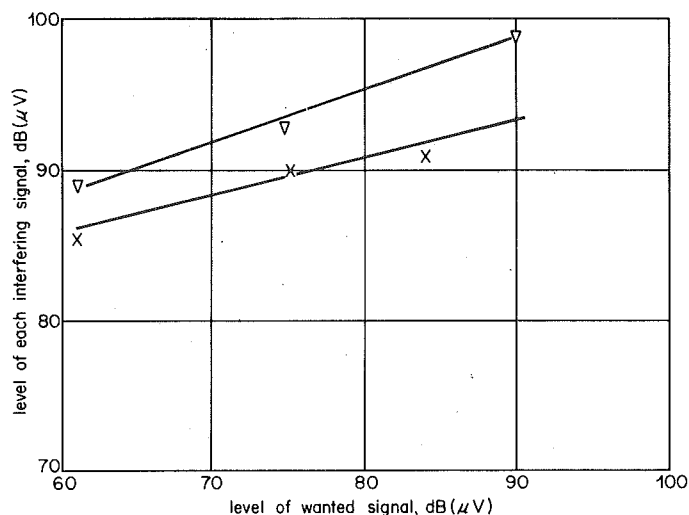

Fig. 6 - The susceptibility of a receiver to intermodulation interference by signals on Channel (n—2) and (n+2) which are equal in amplitude
Receiver A X   Receiver E Δ

5.3.2. Interference by signals on Channels (n+2) and (n—2)

The results for receivers A and E are shown in Fig. 6, in which the levels of equal interfering signals on Channels (n+2) and (n—2) are plotted against the level of the wanted signal on Channel n at which the intermodulating interference is 'just perceptible'. The graphs have slopes between 1/3 and 1/4. If all the a.g.c. action of the receiver had been before a single non-linearity in the receiver's response the slope would have been unity, if after the non-linearity the slope would have been zero. The behaviour of both receivers corresponds more nearly to the second of these conditions. The results of the tests using a single interfering signal (Fig. 5) suggest that the perceptibility of interference at higher levels of the wanted signal than those covered by Fig. 6 would be determined mainly by the level at which either interference is perceptible rather than by an intermodulation product involving both interfering signals. At lower levels of the wanted signal the visibility of the interference would depend on the levels of both interfering signals. If more receivers had been tested, the worst-case condition in Fig. 6 (analogous to Curve 2 in Fig. 5) would probably have been some 10 dB lower than the curve for Receiver E.

6. Interference effects involving three signals at three-channel spacing

6.1. The mechanism of the interference

The three signals involved in the measurement were the BBC-2 transmission on Channel 33, the output from the modulator and frequency convertor on Channel 36 and the c.w. output from a u.h.f. generator set to either Channel 30 or Channel 39.

The mechanism of the intermodulation interference is described in Section 5.1 in connection with the corresponding tests with three signals at two-channel spacings. In addition to these, it is theoretically possible for a receiver tuned to Channel n in the presence of interferences on Channels (n+3) and (n+6) to produce an intermodulation component on Channel (n+9), which is the channel closest to the image signal (of Section 8). In practice the selectivity of the r.f. stages makes this mode of interference negligible compared with the generation of an intermodulation component at the frequency to which the receiver is tuned.

6.2. Method of measurement and results

The equipment used for the measurements was similar to that described in Section 5.2 except that the frequency convertor and associated bandpass filter were tuned to Channel 36, and the c.w. interference was on either Channel 30 (543·25 MHz) or Channel 39 (615·25 MHz), the receiver on test being tuned to either Channel 33 or Channel 36. In this way tests were made on the reception of Channel n in the presence of Channels:

> (a) (n—3) and (n+3)
> (b) (n+3) and (n+6)
> (c) (n—3) and (n—6)

All three tests were performed on Receiver B and each test was also performed on at least one other receiver.

In each test the interfering signals were set to equal peak amplitudes and the wanted signal was adjusted to make the interference 'just perceptible'. However it was found that in each of these tests, which involved wanted signal levels from approximately 40 to 90 dB(μV), if either of the interfering signals in Test (a) or the Channel (n±6) signal in Tests (b) or (c) were switched off, interference was still present, i.e. the threshold of interference was set by the interference due to Channel (n—3) or Channel (n+3) rather than to a three-signal intermodulation effect.

7. Image rejection ratio

7.1. The mechanism of the interference

When a u.h.f. television receiver is correctly tuned to Channel n its oscillator frequency is $O(n) = V(n) + 39·5$ MHz. An interfering signal in the frequency range $O(n) + 33·5$ MHz to $O(n) + 39·5$ MHz could also beat with $O(n)$ to produce a component within the range of the i.f. amplifier. This frequency range, which is from $V(n) + 73$ MHz to $V(n) + 79$ MHz includes much of the spectrum of a television transmission on Channel (n+9) which has a vision carrier frequency $V(n+9) = V(n) + 72$ MHz. The ability of a receiver to reject signals near the image frequency depends on the number of tuned r.f. circuits in the receiver and their selectivity, on the accuracy of ganging of the r.f. and oscillator circuits (i.e. the degree to which the frequency of peak response of the r.f. stages is at the correct constant spacing below the oscillator frequency) and on the accuracy of tuning of the receiver to the wanted signal, which also affects the visibility of the pattern produced.

The image rejection characteristics of domestic television receivers were assessed in two ways, one using objective measurements and the other involving subjective assessments of interference from Channel (n+9). Also the question of interference from Channel (n+10) is discussed.

7.2. Objective assessment of the image rejection ratio

7.2.1. The method of measurement

For each receiver in turn the a.g.c. bias was replaced by a fixed bias, following the instructions for i.f. alignment in the manufacturer's servicing handbook. The output from a signal generator, 100% square-wave modulated at 1 kHz was fed to the receiver. An oscilloscope was used to display the 1 kHz square-wave at the cathode of the receiver display tube, a convenient amplitude being 10 V peak-to-peak.

For several settings of the tuning of the receiver, the signal generator frequency was adjusted for peak response as shown on the oscilloscope and the signal generator output level adjusted to produce a convenient amplitude of oscilloscope trace. The signal generator frequency was then raised by approximately 75 MHz. The tuning was again adjusted for peak response and the generator output level adjusted to produce the same amplitude of oscilloscope trace.

The image rejection ratio was taken as the difference in dB between the two settings of the signal generator output control. This differs from the recommendation of Section 32 of British Standard 3549 : 1969[1] according to which the ratio quoted should be that 'between the minimum input level within the image band and that at vision carrier frequency' for a fixed output level from the receiver. The latter involves the shape of the i.f. and r.f. amplifier characteristics. The ratio quoted in this report involves only the characteristics of the r.f. stages of the receiver, and is numerically about 6 dB greater than the ratio quoted when following B.S. 3549.

This method of measurement is simple, reliable and objective but is open to two criticisms. The first is that the response at the image-signal frequency is measured with a very much higher level of signal than would be tolerable under normal viewing conditions, and the gain of the receiver may be different at the two levels of input signal. It is advisable to check that a small increase in the level of the r.f. input, say 3 dB, produces an equal increase in the amplitude of the oscilloscope waveform. The second objection is that the vision signal to which the receiver is tuned occupies a band of about 5 MHz and is therefore subject to interference from an equally wide band of frequencies, but the simple method of measurement described indicates the protection over only a narrow band of frequencies. Nevertheless, the image response measured by this method is a sufficient guide to the image-band response in view of the limited rate of change of attenuation with frequency in the r.f. circuits.

7.2.2. Results of the objective tests

The variations of the image rejection ratios of

Receivers A, B, C, D and F over the u.h.f. bands, measured by the objective method of Section 7.2, are shown in Fig. 7. It is seen that

(i)   At any one frequency the image rejection ratios of the receivers may differ by up to 15 dB.

(ii)   The variation of image rejection over the u.h.f. bands consists of a slow fall-off with increasing frequency on to which is added a rapid and irregular fluctuation.

(iii) The image rejection ratios measured range from 43 to 68 dB.

7.3. Subjective assessment of the protection ratio required against interference by a signal on Channel (n+9)

7.3.1. Method of measurement

A subjective assessment of the image rejection characteristics of the receivers was made using an interfering signal on Channel (n+9). The carrier frequencies of the channel are $V(n+9) = V(n) + 72$ MHz and $S(n+9) = V(n) + 78$ MHz which beat with the receiver oscillator, $O(n) = V(n) + 39\cdot5$, to produce components at $32\cdot5$ and $38\cdot5$ MHz. The latter frequency is near to the peak of the i.f. response curve and would be expected to be the more likely of the two to produce visible interference on the wanted picture. Observations were therefore made with a c.w. representing the sound carrier of the unwanted transmission. The equipment used was similar to that shown in Fig. 3 except that the modulator, convertor and bandpass filter were replaced by a high-grade u.h.f. c.w. generator. The associated amplifier was not required and the digital frequency meter was connected directly to the output of the generator.

The receiver was tuned accurately to the Channel 33 signal and the frequency of the c.w. generator set to the sound carrier frequency of Channel 42 ($645\cdot25$ MHz). The generator frequency was varied by a few kilohertz, dependent on the tuning of the receiver, to give a pattern with maximum visibility. The interference level was adjusted so that, in its worst condition, the pattern was just perceptible (Grade 2).

Some additional observations were made with both vision and sound signals in Channel 42. These confirmed that, provided that the receivers were tuned accurately (with the vision i.f. close to 39·5 MHz) the interference due to the sound signal was predominant. They also showed that detuning of the receiver could greatly reduce the visible interference, and with the effective vision i.f. near 38·5 MHz, some 10 to 15 dB greater interfering signal levels could be tolerated.

7.3.2. Results

The protection ratios required for just-perceptible interference by a c.w. signal simulating the sound carrier of Channel 42 with a wanted signal on Channel 33, expressed as the ratios of the amplitudes of the equivalent vision carriers, are given for five receivers in Table 2 together with the image rejection ratio for each receiver tuned to Channel 33 taken from Fig. 7.

TABLE 2

Image rejection ratio and required protection ratio for 'just perceptible' interference by a Channel (n+9) sound carrier when the wanted signal is on Channel 33

Receiver	Image rejection ratio at r.f. (dB)	Channel (n+9) protection ratio (dB)	Sum (dB)
A	58	−4	54
B	54	+3	57
C	54	+3	57
D	60	−7	53
F	61	−8	53
Mean	57·4	−2·6	54·8

7.4. Conclusions

With correct receiver tuning, the beat pattern caused by the Channel (n+9) sound signal corresponds to a video frequency of 1 MHz. The CCIR planning data[6] for an
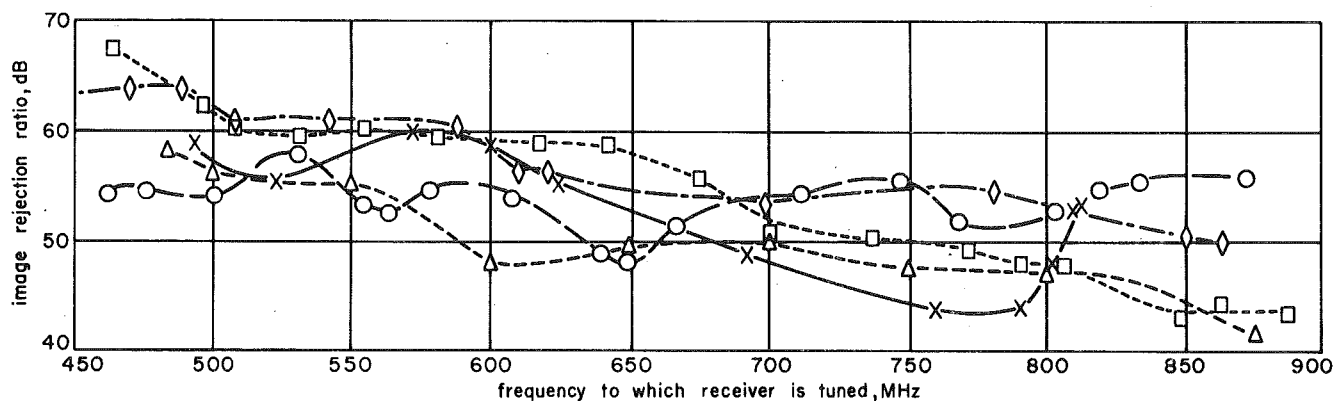

Fig. 7 - The image rejection ratios of five receivers

Receiver A	Receiver B	Receiver C	Receiver D	Receiver F
X——X	O——O	Δ———Δ	□----□	◇—··—◇

interfering sound carrier at a frequency 1 MHz above the wanted vision carrier suggests that the protection ratio for 'tolerable' interference between them should be 50 dB. Allowing for an r.f. image rejection ratio of 54 dB as a typical value found in the objective tests (Section 7.2) and a vision-to-sound carrier level ratio of 7 dB this indicates a required protection ratio of −11 dB. This corresponds to 'tolerable' interference, which is acceptable if present for a small percentage of the time. The subjective results of the previous Section give a protection ratio for just-perceptible interference of from −8 to +3 dB. These figures are in agreement if the usual allowance of 10 to 12 dB additional protection relative to the CCIR planning values is made to correspond to the just-perceptible condition.

We may also note that the final column of Table 2 shows a reasonably consistent value for the sum of the r.f. image rejection ratio and the protection ratio. Therefore the protection ratio for just-perceptible interference at other wanted-channel frequencies may be estimated by subtracting from 55 dB the image rejection ratio shown in Fig. 7.

7.5. Protection ratio required against interference by a signal on Channel (n+10)

A signal on Channel (n+10) will produce, in the intermediate frequency stages of a receiver tuned to Channel n, an image vision signal with a carrier frequency 40·5 MHz. This is 1 MHz from the wanted vision signal in the vestigial sideband region. Reference to the CCIR data[6] for vision interference suggests a corresponding protection ratio of 35 dB for tolerable interference corresponding to about 47 dB for continuous interference. If we now allow the typical r.f. image rejection ratio of 54 dB, found in Section 7.2, the protection ratio for (n+10) with continuous interference is derived as −7 dB. This was not checked by direct experiment in the present series of tests but some earlier tests of dual standard receivers are indicated in Table 3. These are confined to receivers for which it was checked that the optimum tuning position, as used in the tests, corresponded to an effective vision i.f. close to the standard value of 39·5 MHz.

The results of Table 3 show considerable differences between receivers but, in general, there is a greater tolerance of (n+10) signals than is expected from the above calculation. This may be attributed partly to the use of a sharper vestigial cut-off in the receiver than is apparently assumed in the CCIR protection ratio data. For example, the differential attenuation for frequencies at ±1 MHz relative to the carrier is about 20 dB in Receiver A (Fig. 2) compared with the 12 dB difference in the CCIR curve. Another contributing factor is the reversal of the vestigial sideband in the image signal in the receiver. For continuous interference it is suggested that a value of −15 dB (just perceptible interference) would be reasonable for planning purposes, taking into account the typical response of current receivers.

8. Self induced interference caused by feedback of a harmonic of the i.f.

The i.f. stages of a receiver and, particularly, the detector produce harmonics of the i.f. signals, principally of the component corresponding to the vision carrier. Feedback of such a harmonic can, if the frequency is close to that of the received signal, produce an output from the detector in the video band.

Although this type of interference was noted its effects are fleeting, the beat pattern frequency varying at a rate equal to the product of the rate of change of the receiver oscillator frequency and the order of harmonic involved. The effect does not at present appear to be serious, any interference usually only being visible when the wanted picture is free from detail, and no measurements were made relating to it.

9. The r.f. voltage at the aerial socket of a receiver caused by its own local oscillator

9.1. Method of measurement

The local oscillator voltage that appears at the u.h.f. aerial socket of the receiver was measured by the method described in British Standard 905:1968,[2] the equipment used being shown in Fig. 8. The receiver under test stood on a 1·0 x 1·5 m metal sheet and its u.h.f. aerial socket was connected by a short coaxial lead to a 10 dB 75Ω attenuator pad. The output from this attenuator was connected by a 75Ω coaxial lead, approximately 2 m long, and a 75Ω to 50Ω impedance-converting resistive pad to the 10 dB 50Ω attenuator at the input of a standard u.h.f. test receiver. Alternatively, the output from a calibrated u.h.f. oscillator could be injected into the 50Ω attenuator in place of the output from the impedance-converting pad.

The characteristics of these items of test equipment are given in the Appendix, and the precautions required by BS 905 were taken to ensure that the results were not disturbed by direct radiation from the receiver being measured or by standing waves on the coaxial lines.

TABLE 3

Image rejection ratio and required protection ratio for 'just perceptible' interference by Channel (n+10) when the wanted signal is on Channel 45

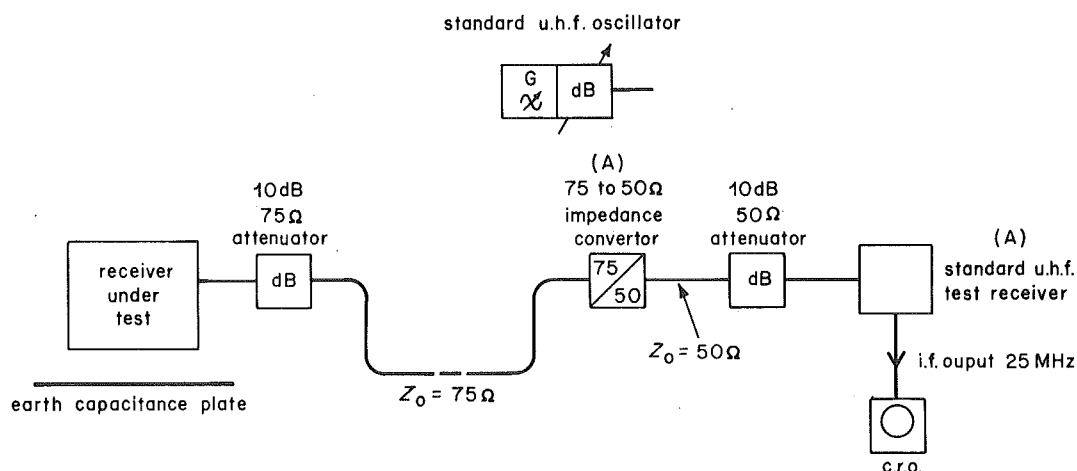| Receiver	Image rejection ratio at r.f. (dB)	Channel (n+10) protection ratio (dB)	Sum (dB)
G	49	−23	26
H	63	−34	29
I	64	−39	25
J	50	−20	30
K	48	− 8	40
Mean	53	−23	30

standard u.h.f. oscillator

Fig. 8 - The method of measurement of the voltage at the aerial socket due to the receiver local oscillator

(A)   Units described in the Appendix to the report

The standard u.h.f. test receiver was tuned to the local-oscillator frequency of the receiver under test and its attenuators adjusted for a standard level of the 25 MHz i.f. output. The signal level was measured by substituting the output from the calibrated u.h.f. oscillator at the same frequency. This was repeated at several other frequencies for Receivers A, B, C and D. Following the recommendation of BS 905 the results are expressed in terms of the voltage developed across a 75Ω impedance at the aerial socket rather than in terms of the effective open-circuit e.m.f.

9.2. Results

The measured oscillator voltage varied with frequency, the results for four receivers operating in the u.h.f. bands being shown in Fig. 9. None of these results lies outside the limit of 60 dB(μV) recommended in BS 905 for a receiver in which mistuning is limited to −2·0 to +0·6 MHz by resulting in unacceptable picture or sound degradation. No measurements were made on receivers operating in the v.h.f.

bands.

BS 905 contains a note that at present no measurements of aerial terminal voltage are made at frequencies above 1000 MHz. It was noticed, however, that Receiver B produced a strong component at the third harmonic of the oscillator frequency, particularly when the latter lay between 570 and 630 MHz. Using the same equipment as for the other tests, except for a change of the standard oscillator to one covering the range 1000 to 2000 MHz, an approximate estimate of the voltage developed at 1800 MHz was 4 mV. Because the attenuators and matching pad were being used at a frequency above their design limit, resulting in calibration errors and in difficulties due to standing waves, this result is liable to an error which may be ±10 dB, but the result shows that the voltage developed by the receiver oscillator at this frequency can be significant. A simple aerial designed for the u.h.f. band can be an effective radiator at the third harmonic of its design frequency leading to fairly high radiation levels unless appreciable attenuation is presented to it by the feeder system.
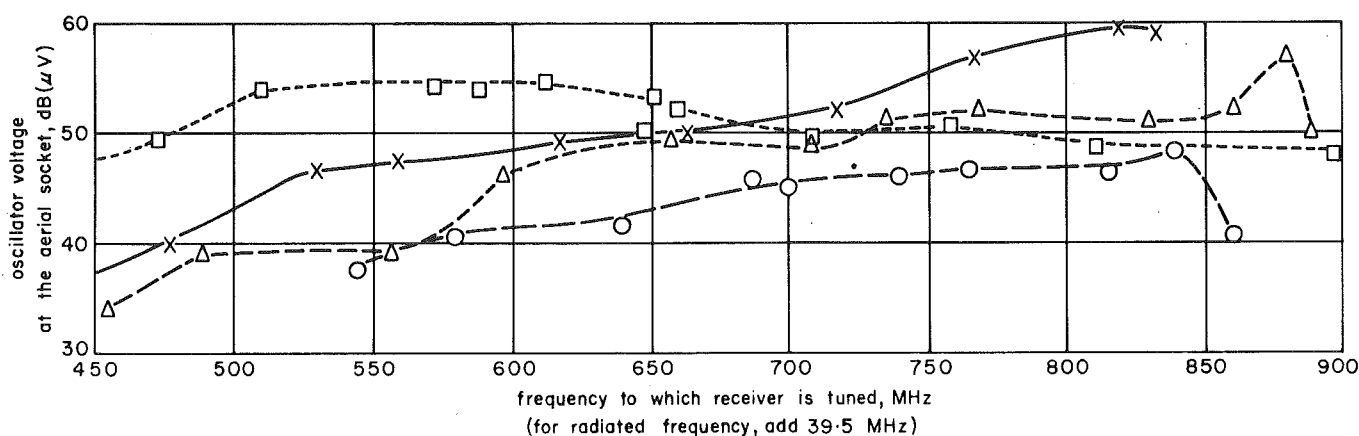

Fig. 9 - The voltage at the aerial socket due to the receiver local oscillator

Receiver A	Receiver B	Receiver C	Receiver D
X———X	O———O	Δ————Δ	□-----□

12

10. Vision a.g.c. performance

10.1. Static a.g.c. characteristics

10.1.1. The nature of the tests

Receivers A and F were tested, each using two different input signals:

(a) A vision signal from the modulator-convertor unit (Section 13.5 of the Appendix), modulated to peak white, without the sound carrier. The amplitude was controlled by an attenuator and calibrated by comparison with the output from a u.h.f. oscillator using the u.h.f. test receiver. (Section 13.2 of the Appendix.)

(b) The output from a u.h.f. oscillator 100% square-wave amplitude modulated at 1 kHz.

For each test the carrier frequency was approximately 500 MHz, and the signal source was matched to the receiver by a 50Ω to 75Ω resistive matching pad.

10.1.2. Tests with a modulated video signal

With the signal level at 90 dB(μV) the receiver was adjusted to give a good video waveform at the display tube cathode, as shown by an oscilloscope with a high-impedance probe, and the video amplitude (black level to white level) was measured. This was expressed in dB relative to 1V. Without changing the receiver controls the input level was reduced step by step, the video amplitude being measured each time. The results for the two receivers are shown in Fig. 10, which are seen to be very similar. As the input level is reduced from 90 to 60 dB(μV) the output level changes by approximately 7 dB.

10.1.3. Tests with a square-wave modulated signal

Measurements similar to those described above were made using an input signal 100% square-wave modulated at 1 kHz, measuring the total amplitude of the signal at the display tube cathode. The results for the two receivers are shown in Fig. 10. It is seen that the two types of measurement give different results and the square-wave modulated signal is not a satisfactory substitute for a video-modulated waveform in assessing the a.g.c. performance of a receiver.

10.2. Dynamic a.g.c. characteristics

10.2.1. The nature of the disturbance

The dynamic characteristics of the a.g.c. system are important when the amplitude of the input signal is variable. Causes of such fading include varying shadowing or reflection effects due to swaying trees and multipath propagation involving reflections from moving objects such as vehicles, aircraft or the surface of the sea.

When the amplitude of change is fairly small, e.g. a flutter of ±10% on the mean amplitude, the most noticeable effects are variations in picture brightness and horizontal
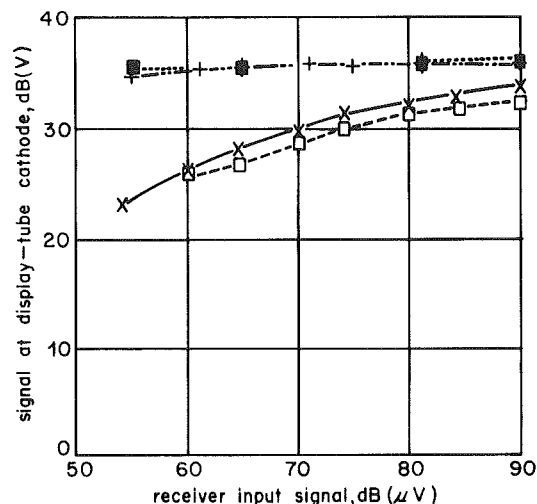

Fig. 10 - Static a.g.c. characteristics

Square-wave modulation,	Receiver A	+----+
	Receiver D	■----■
Video modulation	Receiver A	X---X
	Receiver D	□---□

displacement of the raster. Both occur at flutter frequency, but if this is near to a simple multiple or sub-multiple of field frequency the effect is of a vertically-moving pattern.

The signal used for the tests was a carrier at a frequency of approximately 500 MHz, modulated by a video signal, which was varied sinusoidally in amplitude above and below approximately 10 mV·at a low frequency (0·1 to 100 Hz) using a p.i.n. diode modulator.[9] This signal does not, however, reproduce the frequency-selective fading effects associated with varying multipath propagation of the transmitted signal.

10.2.2. Horizontal displacement of the raster caused by variations of signal amplitude

In most receivers the timing of the line scan synchronising depends to some extent on the amplitude of the signal at the synchronising pulse separator on the time-base triggering threshold and on the base-line level of the synchronising pulse. Among the causes of timing variations are the effects of hum and of field-frequency induced voltages in the time-base circuits.

In these tests the Receivers A and F in turn were tuned accurately to the television signal which was modulated by a grille test pattern. An oscilloscope, which was triggered by the line drive pulses that controlled the grille pattern generator, was used to monitor the timing of the receiver line-scan flyback.

With the low-frequency modulation switched off the timing of the line flyback in Receiver A varied at mains frequency, the amplitude of the excursion increasing and diminishing at a rate equal to the difference between mains and field frequencies — about one cycle in four seconds at the time of these tests — with a maximum peak-to-peak variation of 0·16 μs. The vertical lines of the grille pattern could also be seen to bend at this rate. Receiver F

(ii) frequency-dependent phase shift of the flutter-frequency component in the video amplifiers. In Fig. 12(b) and (c) the variations in the black and white levels are either co-phased or anti-phased. A delay error in the flutter-frequency component causes a phase difference between the variations at black and white levels as shown in 12(d);

(iii) black-level stabilising circuits that are included in some receivers. The behaviour of these circuits varies with the flutter frequency, and the black level is not held constant.

Measurements were made on two receivers. In Receiver A the d.c. gain of the video amplifier was approximately −7 dB relative to that at the middle video frequencies, while in Receiver F there was full d.c. coupling and a d.c. control system operated by the tips of the sync. pulse.

The oscilloscope was used to measure the variations of the black and white levels at the display tube cathode and the 'equivalent percentage modulation' of the black level was defined as 100 times the ratio of the peak-to-peak variation of the black level to the mean of the maximum and minimum black-to-white amplitudes with a similar definition of the equivalent percentage modulation of the white level. Fig. 13 shows that at flutter frequencies above 20 Hz for Receiver A and 50 Hz for Receiver F the variation of white level was fairly small but the variation at black level was very closely that to be expected from 10% modulation of the input without effective a.g.c. This brightness variation was disturbing to the viewers (Grades 4 to 5 on the EBU six-point impairment scale) and even 5% modulation was found to have a marked effect (Grade 3 to 4).
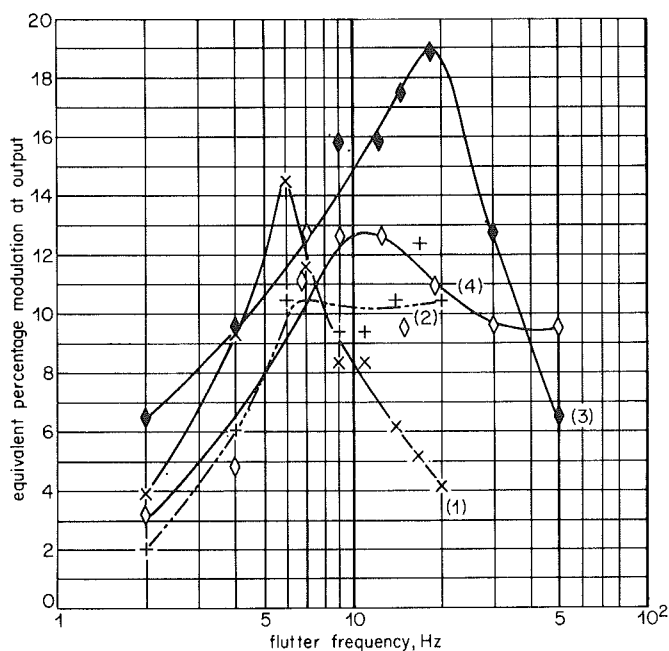

Fig. 13 - Dynamic a.g.c. characteristics : variations of black and white levels due to ±10% variation of signal amplitude

X Receiver A, White level   + Receiver A, Black level
◊ Receiver F, White level   ◊ Receiver F, Black level

When the flutter frequency was reduced the fluctuations of the white level rose to a peak at approximately 6 Hz for Receiver A and 20 Hz for Receiver F. At frequencies close to the peak the variation of the white level is considerably greater than the 10% variation of the input signal and the black-level variation is also at or a little above 10%. Under these particular conditions the variation of signal amplitude at the display tube can thus be appreciably worsened by the a.g.c. system.

At still lower frequencies the a.g.c. became effective and the variations of *brightness* were just perceptible (Grade 2) for 10% modulation at 0·5 Hz for Receiver A and 0·2 Hz for Receiver F. With 5% modulation the variation of brightness was just perceptible at 0·75 and 0·4 Hz respectively. These results were virtually independent of the mean level of the signal, but with low amplitude signals the fading was apparent from the variation of noise on the picture.

10.3 Discussion of the results

Signal amplitude variations due to normal fading usually occur slowly (say, at less than 1 Hz) and the a.g.c. system reduces their effects on the display tube brightness.

On the other hand the a.g.c. system are much less effective for flutter rates above about 5 Hz. Undue disturbances can occur at certain rates of flutter because some a.g.c. systems increase rather than reduce the amplitude of the fluctuations, particularly the white-level variation. This shortcoming is more significant at u.h.f. since fast flutter rates caused by reflections from moving objects will be more common at u.h.f. than at v.h.f.

The tests were made on dual-standard receivers, in which the design of the a.g.c. circuits tends to be a compromise between the requirements of the positive modulation used in 405-line System A and the negative modulation used in 625-line System I. The characteristics of single-standard receivers may be different. Only monochrome receivers were tested and other factors, such as the effects of chrominance a.g.c. circuits, would have to be taken into account if colour receivers were tested.

11. Conclusions

11.1. Protection ratios

The protection ratios for just-perceptible interference from other television signals at the more important channel spacings have been found for a group of domestic receivers and the results described in Sections 3, 4, 5, 6 and 7 and the appropriate figures. These results have been collected in Fig. 14 in the form of graphs of protection ratio versus input signal level. This ratio is required for protection against continuous interference, which often occurs for the channel spacings considered. The values are not directly comparable with those given in the CCIR recommendation[6] since these are for interference present for a small percentage of the time. As discussed in the body of the report, however, for spacings where a comparison is possible, the receiver performance is on the whole con-

sistent with the CCIR data after making a reasonable allowance for the different percentage of time.
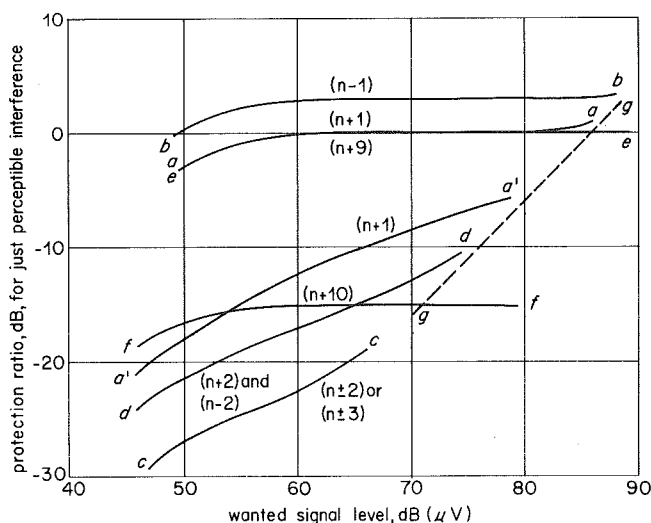

Fig. 14 - Protection ratios for just-perceptible interference from other television channels

Key	Interfering Channel	Notes	Reference
a	(n+1) upper adjacent	practical limit	Sec. 3
a'	(n+1) upper adjacent	transmitter filter giving greater l.s.b. attenuation	Sec. 3 Fig. 4 curve 2
b	(n−1) lower adjacent		Sec. 3 Fig. 4 curve 1
c	(n±2) or (n±3)	singly	Sec. 4 Fig. 5 curve 2
d	(n+2) and (n−2)	together (worst estimate)	Sec. 5
e	(n+9)	image sound	Sec. 7.3.2. Table 2
f	(n+10)	image vision	Sec. 7.5 Table 3
g		asymptote for all curves except (e) and (f)	Sec. 11

Referring to Fig. 14, curves (*a*) to (*d*) are asymptotic to curve (*g*), which represents an interfering signal level of 86 dB(μV). Just-perceptible cross-modulation from a neighbouring channel occurs, at all levels of the wanted signal, for an interfering signal level close to this value in most of the receivers tested. Cross-modulation from more remote channels occurs at a much higher level as shown by curves (*e*) and (*f*) owing to the greater attenuation of the r.f. circuits.

11.2. Other characteristics

Sections 8 and 9 indicate that there is little tendency for receivers to be significantly affected by i.f. harmonic feedback or to exhibit undue leakage of local oscillator power except for one case where the level of the third harmonic was excessive. The dynamic response of the a.g.c. circuits of some receivers shows certain undesirable resonances as described in Section 10.

12. References

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2. British Standard 905 : 1969. Radio interference limits and measurements for television and VHF sound receivers.

3. CCIR Documents of the XII Plenary Assembly, New Delhi 1970, Vol. V, Part 2, Report 405-1, Note 8, p. 90.

4. van WEEL, A. 1958. Design of detector stages for signals with symmetrical or asymmetrical sidebands. *J. Br. Instn Radio Engrs.*, 1958, **18**, 9, pp. 525 − 538.

5. The pulse response of some domestic u.h.f. television receivers, and its relation to the amplitude and group-delay characteristics. BBC Research Department Report No. RA-27, Serial No. 1968/57.

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7. WHARTON, W. 1965. Vestigial-sideband transmission at u.h.f. *Proc. Instn. elect. Engrs.*, 1965, **112**, 12, pp. 2199 − 2207.

8. U.H.F. television: the interference caused by a receiver operating on channel n to an adjacent receiver tuned to channel n+4. BBC Research Department Report No. 1970/9.

9. BROWN, A. *and* SUSANS, D.E. 1970. A prototype adaptive receiving system for application to u.h.f. television rebroadcast links. International Broadcasting Convention, IEE Conference Publication No. 69, Sept. 1970, pp. 64 − 67.

13. Appendix:

Equipment used in the measurements

13.1. General

Some items of test equipment were used in several tests and features of interest are given here to avoid repetition in the main text.

13.2. U.H.F. test receiver

The receiver is of the superheterodyne type with an i.f. of 25 MHz and an untuned r.f. circuit. It can be tuned to a signal in the range 280 to 940 MHz using the fundamental frequency of the local oscillator and up to 4600 MHz using the third or fifth harmonic of the local oscillator. The i.f. stages include an attenuator calibrated in dB and a simple crystal-diode voltmeter which indicates the signal level at the output of the i.f. amplifier. Of the alternative output connections, the two generally used in the tests were a narrow-band a.f. output for headphones and an i.f. output at 60Ω impedance with a bandwidth of 2 MHz. An oscilloscope connected to this output was used to assess the signal peak amplitudes. Because of the bandwidth limitations the amplitude of a carrier modulated by a vision signal was measured on the field synchronising pulses. The input impedance of the receiver is not defined so it was always used with a 10 dB 50Ω attenuator.

13.3. Impedance matching pads

Resistive pads were used as matching devices between 50Ω and 75Ω circuits. In particular that used with the u.h.f. test receiver (13.2 above) approached 'minimum loss' design: when fed from a 75Ω source and loaded by 50Ω the *voltage* attenuation was 7·8 dB and when used in the reverse direction it was 4·2 dB.

13.4. 3 dB directional couplers

Each coupler has four 50Ω coaxial connections which may be considered as being at the corners of a rectangle. If all four are connected to 50Ω sources or loads, power fed into any one socket is shared equally between the two adjacent sockets, with negligible power into the load at the diagonally opposite socket.

If two sources feed into diagonally opposite sockets then, subject to reasonably good matching, the power from each is shared equally between the loads on the other sockets without power from one source being driven into the other.

13.5. Sound and vision modulators and frequency convertor

A carrier at 57 MHz is modulated by either a video test signal or the output from a slide scanner, using negative modulation a.m., and a 63 MHz carrier, frequency modulated at a.f. with a peak deviation at 100% modulation of 50 kHz, is generated by heterodyning an unmodulated carrier at 57 MHz with a frequency-modulated carrier whose mean frequency is 6 MHz to an accuracy better than 1 kHz. The two carriers are added linearly with a 7 dB vision-to-sound peak carrier ratio. The sum is passed through a filter, simulating the v.s.b. characteristics of a u.h.f. transmitter, to a frequency convertor with a continuously variable oscillator which raises the frequency into the u.h.f. band. The output vision carrier frequency is normally the sum of the input frequency (57 MHz) and the oscillator frequency of the convertor but output signals are produced both at the difference frequency (with an inverted frequency spectrum and with the sound channel 6 MHz below the vision channel) and as a direct break-through of the convertor oscillator. These spurious signals were removed by a band-pass filter, with a bandwidth of 10 MHz extending from just above the wanted sound carrier frequency to approximately 1·5 MHz below the wanted vision carrier frequency.

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